BLIP Raster System
Project Closeout Review

Rob Michnoff

(on behalf of the entire team)

Outline

- Motivation and Project Initiation
- Project Mission and Purpose
- Project Scope
- Key Performance Parameters (KPPs) and Ultimate Performance Parameters (UPPs)
- Project Status and Performance
- Schedule, Financials, Milestones
- Environmental, Safety, Security, Health and Quality (ESSHQ)
- Discussion of systems, beam data and final installation
- Issues that arose
- Recommended Use of Remaining Funding
- Lessons Learned
- Summary

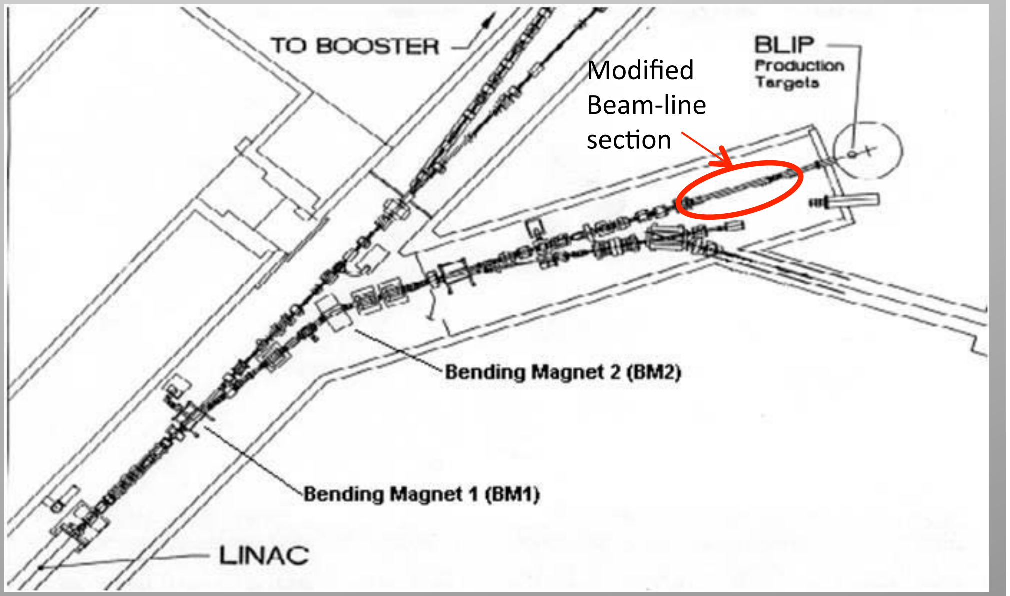
Motivation and Project Initiation

- The design and installation of a beam raster system at the Brookhaven Linac Isotope Producer (BLIP) will increase isotope yield and sharply reduce target fatigue.
- After technical, cost, schedule and management review in Sept. 2013, the $4.5M baseline and schedule for the Raster Accelerator Improvement Project (AIP) was approved by the Office of Nuclear Physics (ONP) in Dec. 2013.
- As a result of the Sept. 2013 review, ONP requested that the project be completed in 2 shutdown periods instead of the originally proposed 3 shutdown periods.
  - May 2016 was the revised early finish date
  - System began being used operationally in January 2016

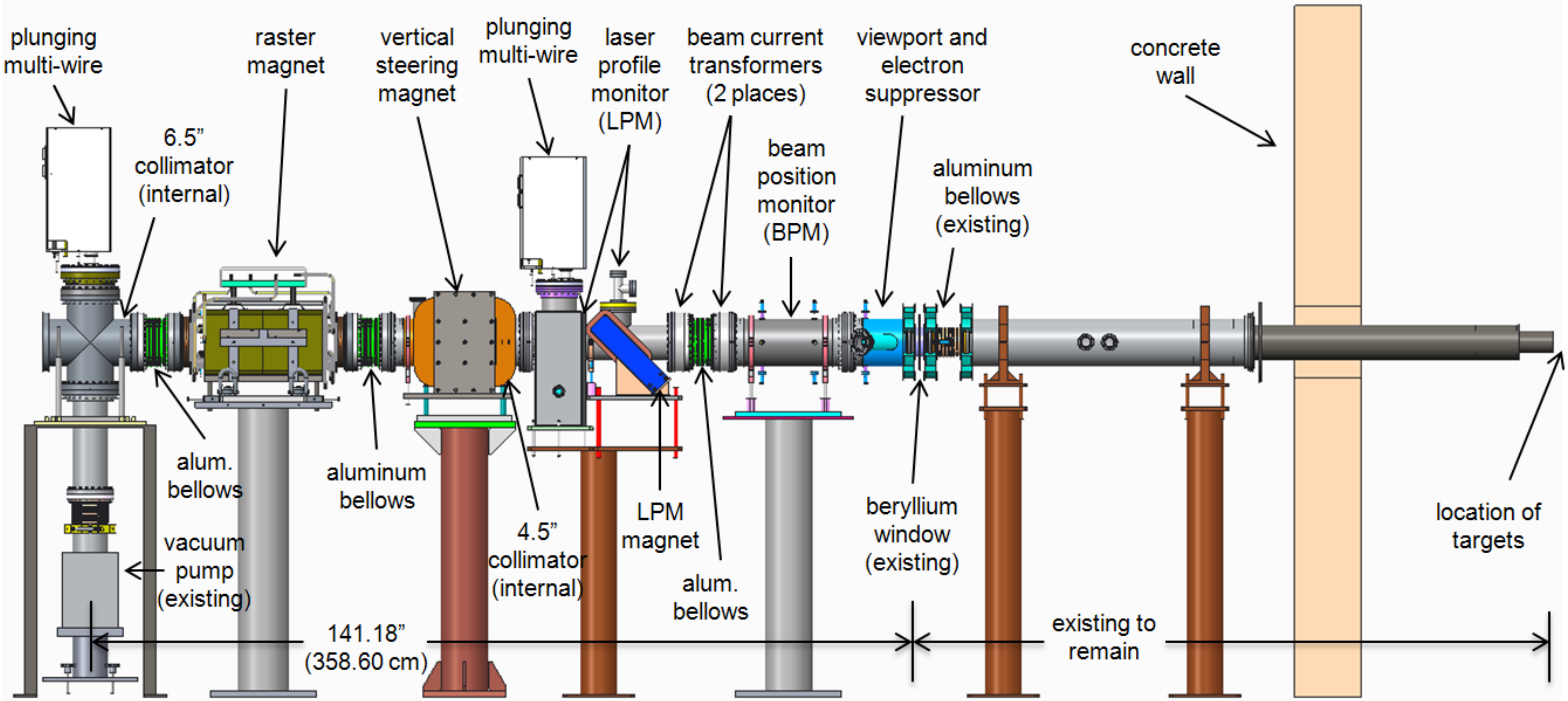
Project Mission/Purpose

- The purpose of the BLIP raster system is to “paint” the beam in a circular fashion to provide an even distribution of beam on the BLIP target by spreading out the power density.
- Project included installation of several new beam instrumentation devices.

LINAC building, BLIP building and BLIP beam line



New beam-line layout
Installation completed December 2015



Project scope: Design, fabricate, install and commission a BLIP Raster system containing the components shown in the beam-line layout, and including all required mechanical, electrical and software systems.

Key Performance Parameters (KPPs)

- The Key Performance Parameters (KPPs) that define successful completion of the project are:
  - ✓ The raster magnets, power supply and associated beam-line vacuum components and electronic equipment are installed. This includes components in the tunnel as well as in the BLIP control room.
  - ✓ **The beam is modulated horizontally and vertically to produce 5 kHz circular rastering** of the beam with a fixed radius on the BLIP target.
  - ✓ The beam intensity is limited to 125 microAmps, the intensity that is currently used for non-rastered operation in order to provide additional safety against target damage.

Ultimate Performance Parameters (UPPs)

- **The circular rastering of the beam is configurable to occur at 2 different radii.** The anticipated operation is to raster the beam at a radius of 19.5 mm for 3 consecutive 450 microsecond long pulses (2.25 rotations per pulse), then raster the beam at a radius of 6.5 mm for one pulse, and repeat the pattern.
    - Table of many different radii can be configured
    - X and Y amplitudes can be different to create oval pattern
    - Achieved 260 Amps continuous amplitude, which equates to 20.9 mm radius at 117 MeV and 15.6 mm radius at 200 MeV.

✓ The **beam interlock system** allows an average beam current of 140 microAmps.

- Actual typical operating current achieved: 160 microAmps

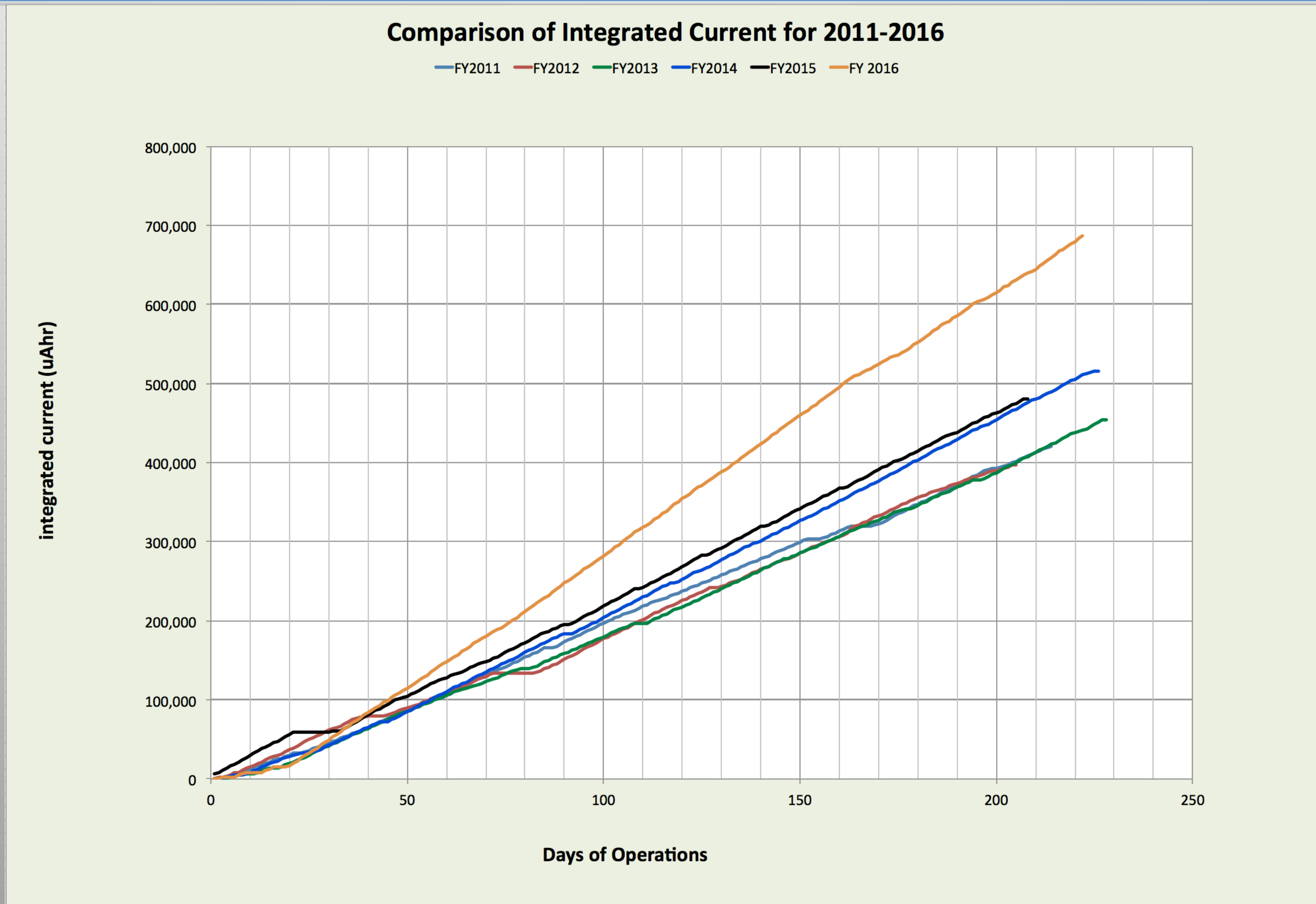
Status

- Installation was completed December 2015.
- Isotope production with rastering began January 4, 2016.
- Key performance parameters have been satisfied.
- Ultimate performance parameters have been satisfied with 1 exception.

The UPP in question:
The circular rastering of the beam is configurable to occur at 2 different radii. *The anticipated operation is to raster the beam at a radius of 19.5 mm for 3 consecutive 450 microsecond long pulses (2.25 rotations per pulse), then raster the beam at a radius of 6.5 mm for one pulse, and repeat the pattern.*

◆ We recommend that the UPPs be closed with the understanding that the raster radius will be limited to 15 mm maximum at 200 MeV with no sacrifice to the isotope research and production program based on the present and foreseeable future beam operating conditions. Based on studies with beam, 15 mm radius is expected to be the maximum needed for optimal coverage and this can be satisfied for 200 MeV with 260 amps peak current.

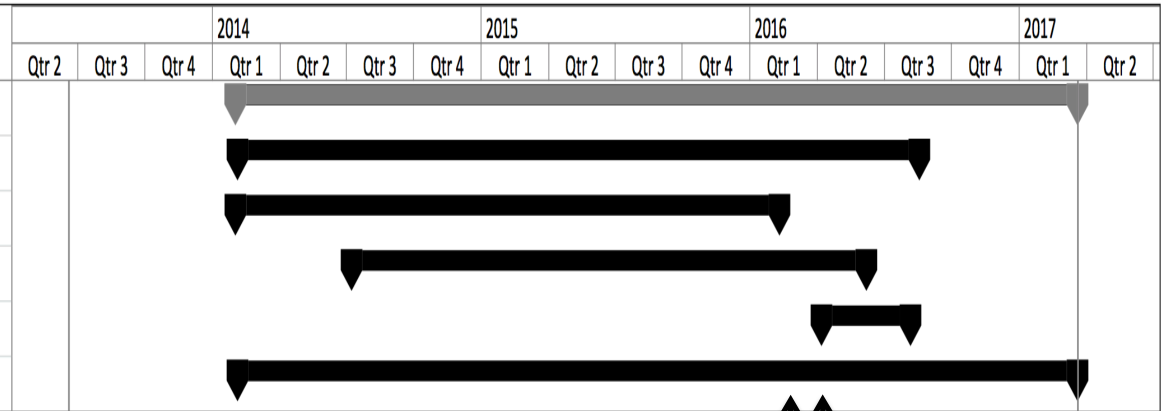
Performance



- Total integrated current increased 48% from 2015 to 2016
- Increase in yield (mCi/µAh) due to rastered beam has been calculated to be 9%

High Level Schedule

WBS	Task Name	% Complete	Start	Finish
1.	Raster AIP	100%	11/1/13	12/19/16
1.1	Management	100%	11/4/13	5/18/16
1.2	Construction	100%	11/1/13	11/10/15
1.3	Installation	100%	4/8/14	3/7/16
1.4	Commissioning	100%	1/6/16	5/6/16
1.5	Project Milestones (High Level)	100%	11/4/13	12/19/16



Actual commissioning with beam began Dec 16, 2015
(planned start of commissioning was Jan. 12, 2016)

Isotope production with beam began Jan. 4, 2016
(planned confirmation of rastering was May 19, 2016)

- KPPs and most UPPs were satisfied in January 2016, 4 months earlier than the planned date of May 2016.

Financials as of June 2016

Raster AIP			FY14 Actuals	FY15 Actuals	FY16 Actuals	Project to date (PTD) costs*	Burdened Commit-ments	Cost & commit-ments	Original Budget at Comple-tion	Budget Changes	Current Budget at Comple-tion	Current Budget less actuals / commts
WBS	Account #	Title										
1.1	70047	Management	56.2	160.2	44.8	261.3	-	261.3	266.4	0.0	266.4	5.1
1.2		Construction	1,490.6	1,466.2	353.0	3,309.8	-	3,309.8	2,888.0	316.0	3,204.0	(105.8)
1.2.1	*70048*	*Instrumentation*	*825.5*	*664.4*	*37.9*	*1,527.8*	-	*1,527.8*	*1,931.6*	*32.0*	*1,963.6*	*435.8*
1.2.2	*70049*	*Magnet and Vacuum*	*458.8*	*416.3*	*87.4*	*962.5*	-	*962.5*	*645.6*	*130.0*	*775.6*	*(186.9)*
1.2.3	*70050*	*Power Supplies*	*206.3*	*385.5*	*227.7*	*819.5*	-	*819.5*	*310.9*	*154.0*	*464.9*	*(354.6)*
1.3	70051	Installation	99.1	149.1	30.9	279.1	-	279.1	510.9	5.0	515.9	236.7
1.4	70052	Commissioning	-	-	-	-	-	-	81.6	0.0	81.6	81.6
1.x		Post-Commissioning	-	-	-	-	101.5	101.5		349.0	349.0	247.5
1.x.x	*70054*	*BM1 Power Supply*	-	-	-	-	*101.5*	*101.5*	-	*249.0*	*249.0*	*147.5*
1.x.x	*70076*	*Misc. Spare Equipment*	-	-	-	-	-	-	-	*0.0*	-	-
1.x.x	*70077*	*Spare Raster Magnet*	-	-	-	-	-	-	-	*0.0*	-	-
1.x.x	*70078*	*Ga Target Failure Analysis*	-	-	-	-	-	-	-	*100.0*	*100.0*	*100.0*
	70053	Contingency	-	-	-	-	-	-	753.0	(670.0)	83.0	83.0
		Total (Actual Cost of Work Performed)	1,645.9	1,775.6	428.7	3,850.2	101.5	3,951.7	4,499.9	0.0	4,499.9	548.2

All values are in $k and include labor and materials

NOTES:

- Original estimated cost without contingency: $3746.9k
- Cost to complete project KPPs and UPPs: $3850.2k (86% of baseline budget including contingency)
- Actual contingency used: $103.3k of original $753k (14%), or 2.8% of estimated cost ($3746.9k)
- Remaining funding after project completion: $649.7k
- Of remaining $649.7k, $349k was approved for additional scope in May and June 2016
- Propose to use remaining $300.7k to purchase spare equipment
- Commissioning expenditures were applied to associated construction accounts

Schedule Performance – Project Milestones

Reporting Milestones	Planned date	Actual date
Project Start	Nov 4 2013	Nov 4 2013 (A)
Designers assigned to project	1QFY14	1QFY14 (A)
Access BLIP Spur	1QFY14	1QFY14 (A)
PM trip to LANL	2QFY14	3QFY15 (A)
Current Transformers ordered	2QFY14	2QFY14 (A)
Material ordered for Plunging Multiwire Profile monitor	2QFY14	2QFY14 (A)
Decision on Rad Hard vs. periodic replacement	3QFY14	3QFY14 (A)
Design Review & Accelerator Systems Safety Review	4QFY14	3QFY14(A) / 1QFY15(A)
Summer/Fall 2014 access to BLIP Tunnel	1QFY15	1QFY15(A)
All power supply purchases received	2QFY15	2QFY15 (A)
Vacuum fabrication begins	3QFY15	4QFY14 (A)
Magnet stand fabrication begins	3QFY15	1QFY15 (A)
Vacuum Chamber pumpdown	4QFY15	1QFY16 (A)
Summer/Fall 2015 access for BLIP Tunnel Installation	4QFY15	4QFY15 (A)
Raster magnet available for installation	1QFY16	1QFY16 (A)
Plunging Multiwire Profile Monitor available for installation	1QFY16	1QFY15 (A)
Accelerator Systems Safety Review-installed	1QFY16	1QFY16 (A)
Power supply installation	2QFY16	1QFY16 (A)
DOE approval to operate	2QFY16	Internal approval 1QFY16
Begin Raster System test without beam	3QFY16	1QFY16 (A)
Confirmation of Rastering	4QFY16	1QFY16 (A)
Project complete	1QFY17	2QFY16 (A)

All milestones have been achieved, many earlier than planned

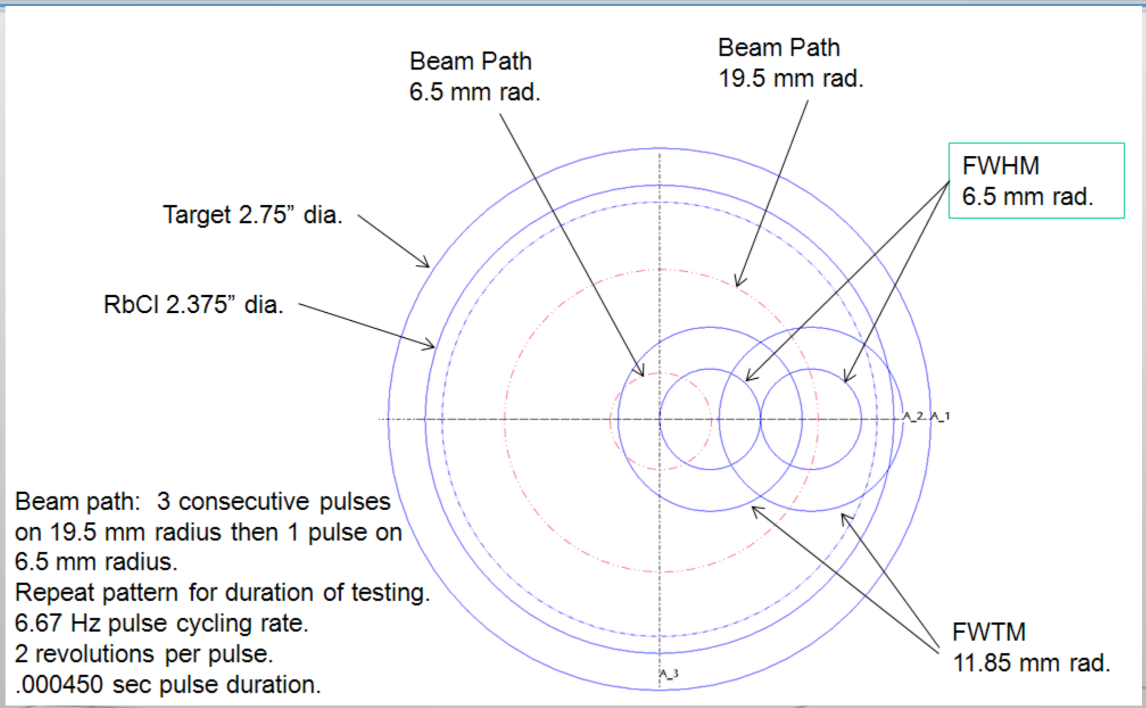
ESSHQ
(Environmental, Safety, Security, Health and Quality)

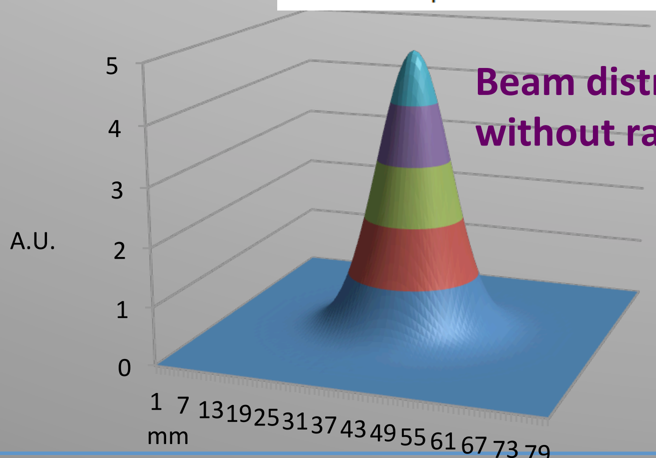
- Estimated dose for installation work was 2000 person mrem. Actual accumulated dose was 2068 person mrem. Approximately 50 people worked under the RWPs (radiation work permits)
- The beam-line equipment was preassembled in non-radiation lab to decrease time required for installation in the high radiation beam tunnel.
- Radiation Control Division (RCD) staff successfully decontaminated the primary work area.
  - This prevented the need for workers to wear contamination PPE, thus making work in the area more efficient and limiting accumulated dose.
- RCD staff installed temporary shielding to limit dose rates in the tunnel work area.

ESSHQ
(Environmental, Safety, Security, Health and Quality)

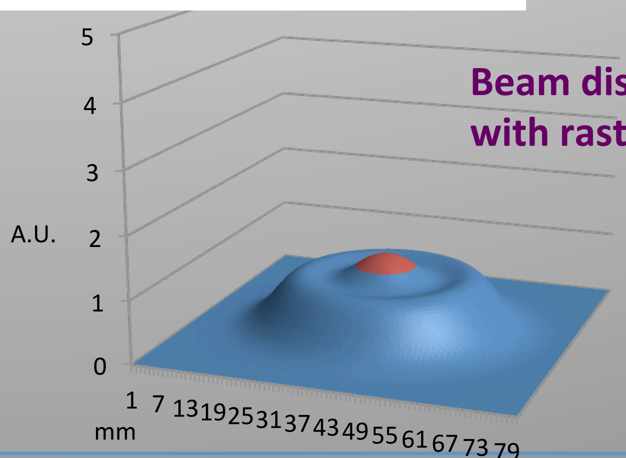
- Extended concrete rain barrier cap over BLIP beam-line berm in order to limit potential for contaminating rain water runoff
- Reviews were conducted by the following committees to ensure that all aspects of safety were identified, addressed and approved:
  - Radiation Safety Committee (RSC), including shielding design approval
  - Accelerator Systems Safety Review Committee (ASSRC), including conventional safety issues and electrical compliance

Raster motion and distribution on target (simulation)





Beam distribution without raster



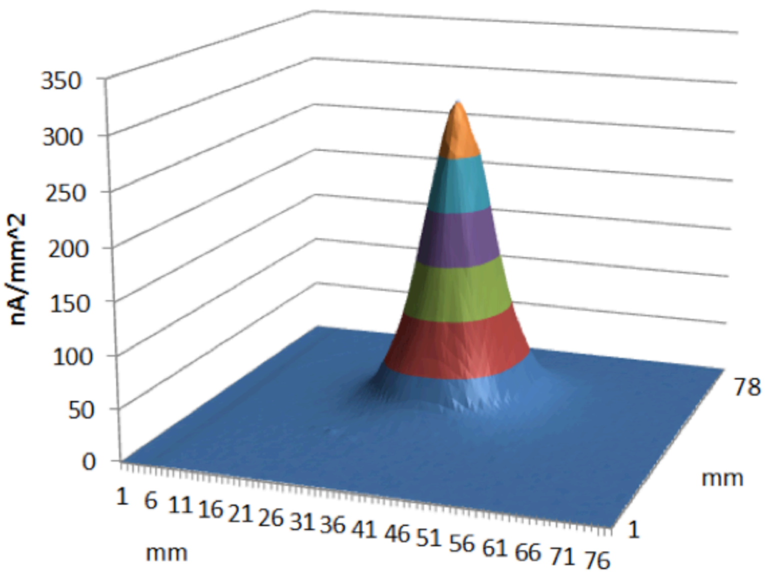
Beam distribution with raster

Integral of beam distribution is the same for both plots

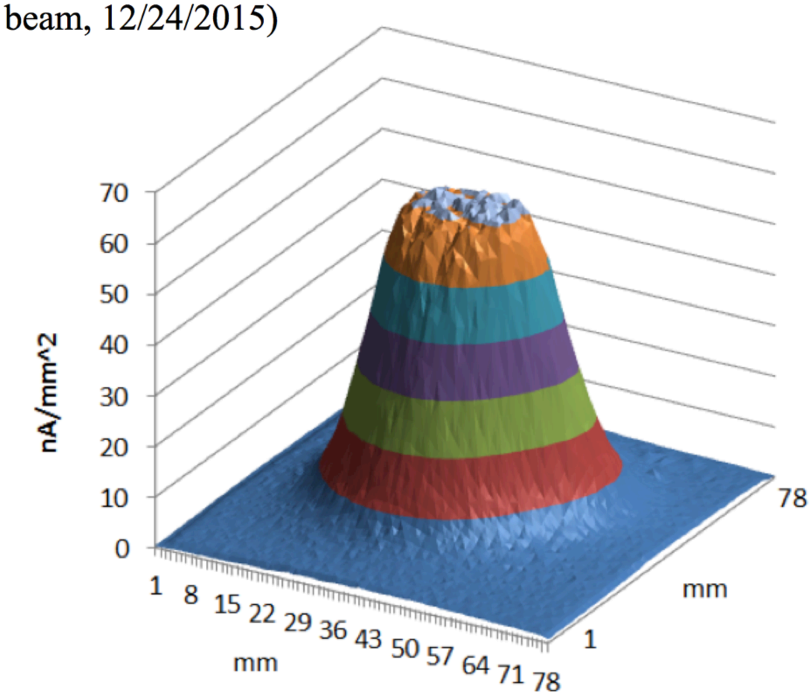
Distribution on target
(Foil phosphor images with beam, 117 MeV)

(D. Raparia, J. Nalepa)

Beam distribution on target, 117 MeV, 100 μA
(Foil phosphor images with beam, 12/24/2015)



Beam distribution without raster
FWHM: 13 mm
FWTM: 40 mm



Beam distribution with raster
FWHM: 32 mm
FWTM: 60 mm

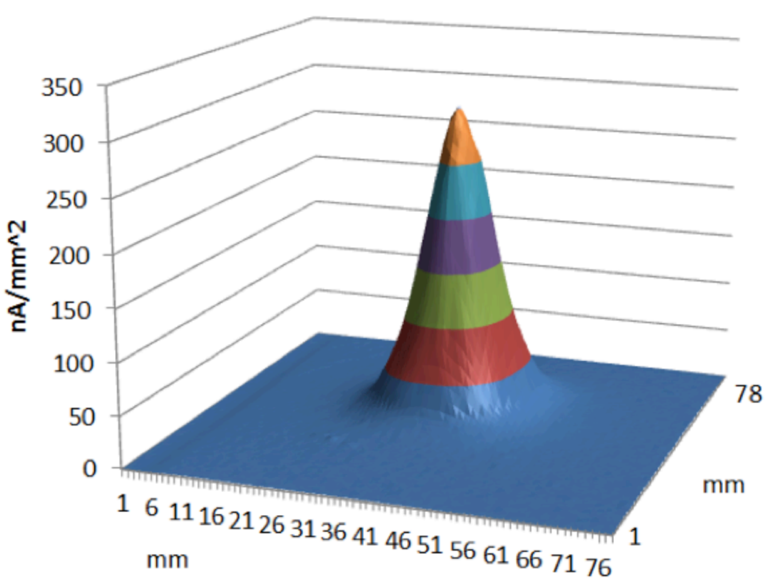
Repeating raster pattern:
- 4 linac beam pulses at 11.5 mm (143 amps peak)
- 1 linac beam pulse at 4.5 mm (58 amps peak)

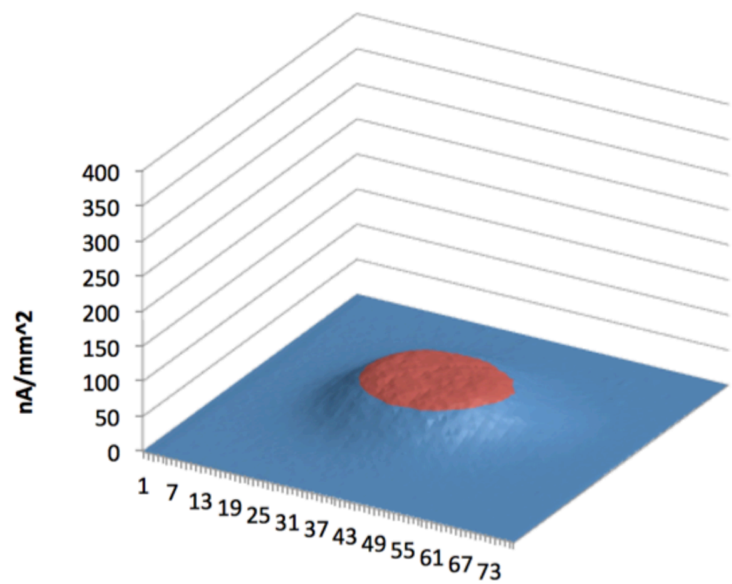
- **Integral of beam distribution is the same for both plots**
- **Note different y-scales**

Distribution on target
(Foil phosphor images with beam, 117 MeV)

(D. Raparia, J. Nalepa)

Beam distribution on target, 117 MeV, 100 µA
(Foil phosphor images with beam, 12/24/2015)





Beam distribution without raster
FWHM: 13 mm
FWTM: 40 mm

Beam distribution with raster
FWHM: 32 mm
FWTM: 60 mm

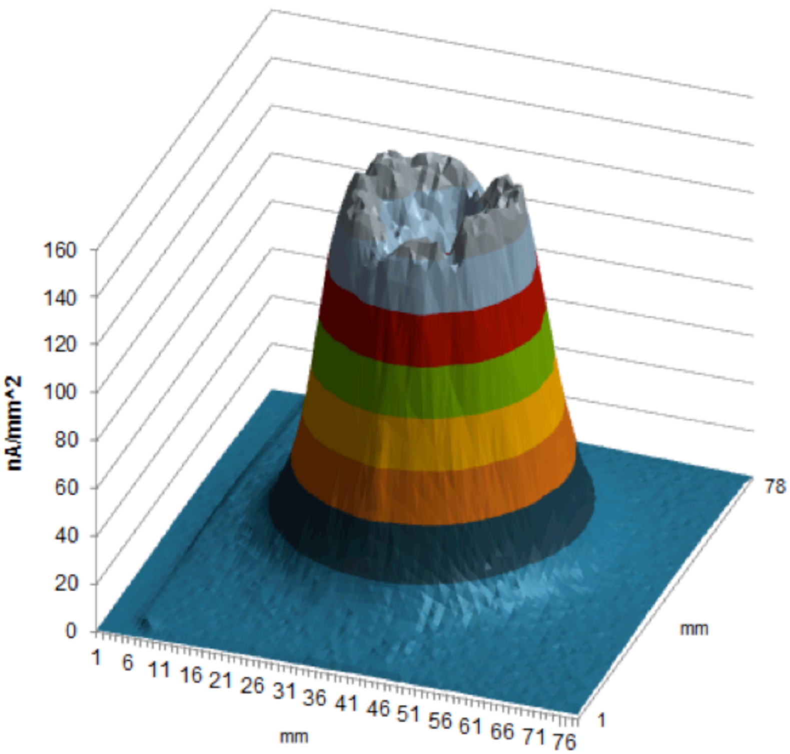
Repeating raster pattern:
- 4 linac beam pulses at 11.5 mm (143 amps peak)
- 1 linac beam pulse at 4.5 mm (58 amps peak)

- **Integral of beam distribution is the same for both plots**
- **Same data as previous slide but with similar y-scales**

Distribution on target
(Foil phosphor image with beam, 117 MeV)

(J. Nalepa)

Beam distribution on target, 117 MeV, 155 µA
(Foil phosphor image with beam, 3/25/2016)



Beam distribution with raster
FWHM: 34 mm
FWTM: horiz: 57 mm, vert: 55 mm

Repeating raster pattern:

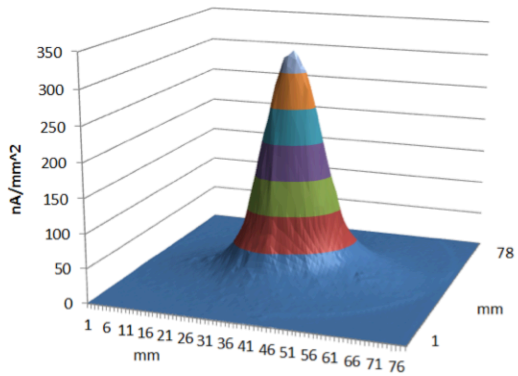
- 4 linac beam pulses at 12.5 mm (155 amps peak)
- 1 linac beam pulse at 5.5 mm (71 amps peak)

This phosphor image was taken after non-rastered beam profile was decreased to:
FWHM: 10 mm
FWTM: 23 mm

Distribution on target
(Foil phosphor images with beam, 200 MeV)

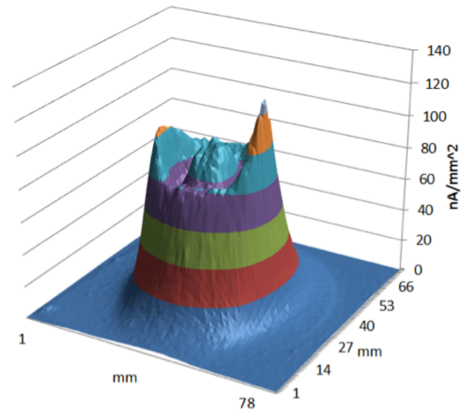
(J. Nalepa)

Beam distribution on target, 200 MeV, 115 μA
(Foil phosphor image with beam, 2/24/2016)



Beam distribution without raster
FWHM: 15 mm horizontal, 12 mm vertical
FWTM: 23 mm horizontal, 26 mm vertical

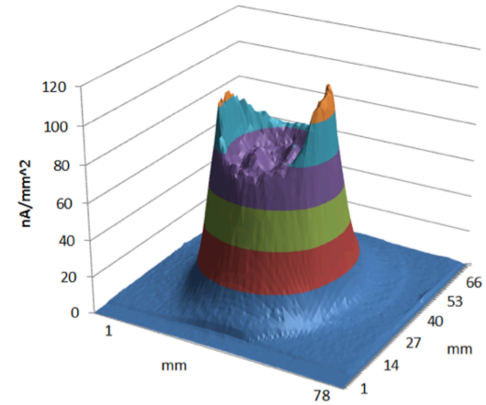
Beam distribution on target, 200 MeV, 140 μA
(Foil phosphor image with beam, 2/24/2016)



Beam distribution with raster
FWHM: 37 mm horizontal, 35 mm vertical
FWTM: 56 mm horizontal, 47 mm vertical

Repeating raster pattern:
- 4 linac beam pulses at 13.5 mm (225 amps peak)
- 1 linac beam pulse at 4.5 mm (75 amps peak)

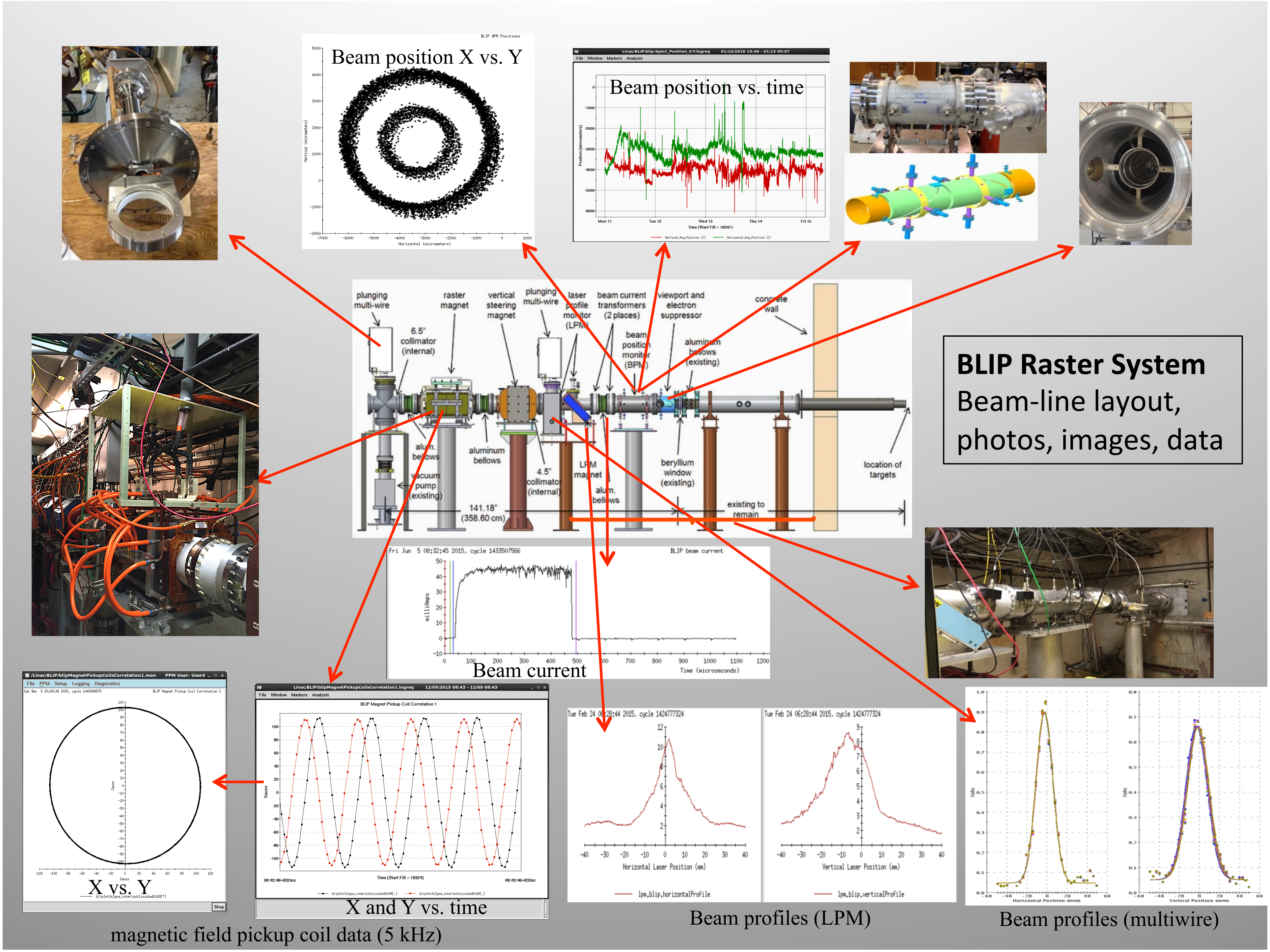
Beam distribution on target, 200 MeV, 140 μA
(Foil phosphor image with beam, 2/25/2016)



Beam distribution with raster
FWHM: 34 mm horizontal, 35 mm vertical
FWTM: 59 mm horizontal, 50 mm vertical

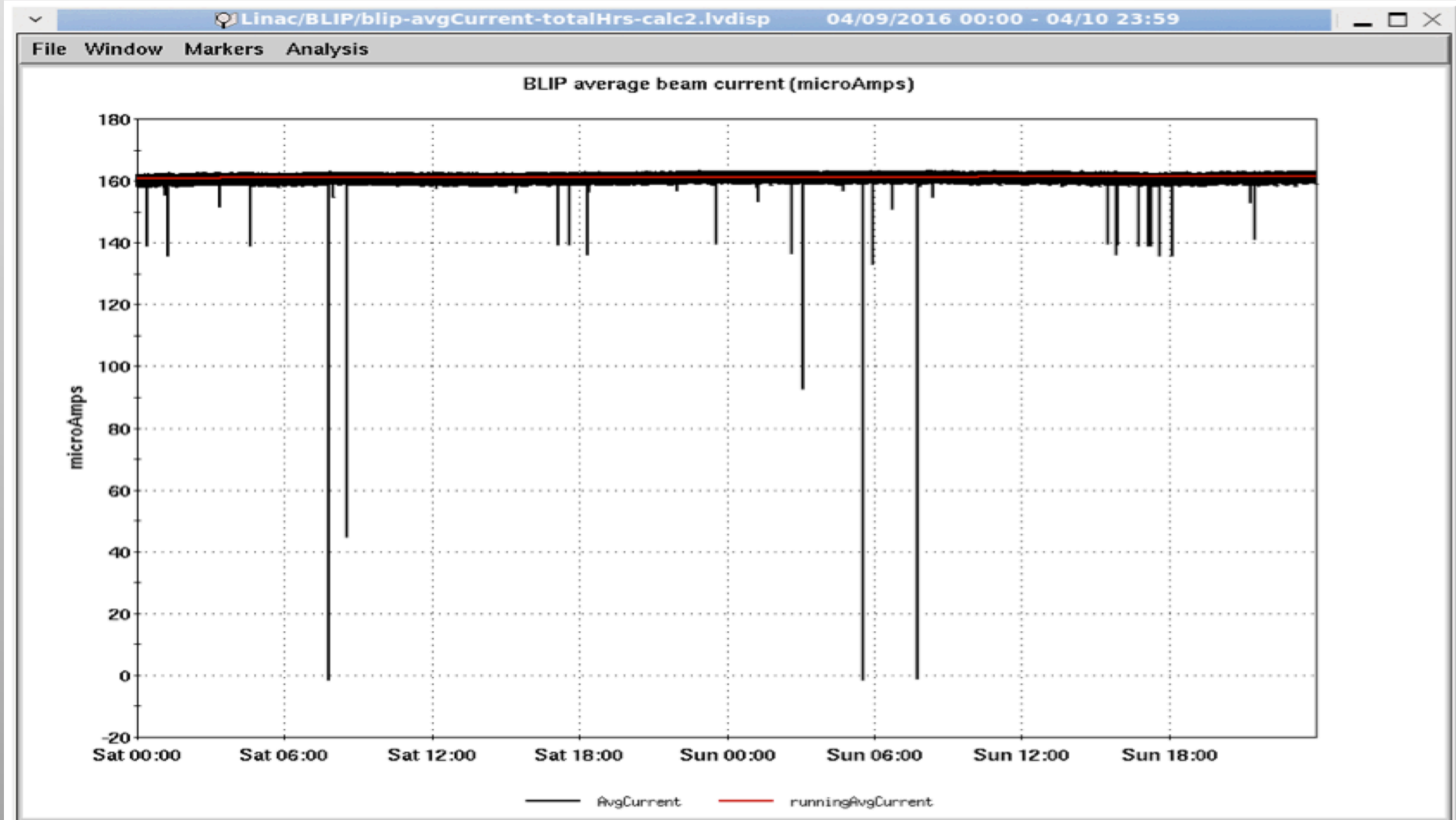
Repeating raster pattern:
- 4 linac beam pulses at 13.5 mm (225 amps peak)
- 1 linac beam pulse at 5.5 mm (92 amps peak)

- Note that the image on the right with 5.5 mm inside radius has a crater in the center, while the middle image with 4.5 mm inside radius does not.
- Optimal beam raster patterns continue to be explored.
- The pattern is programmed by entering a list of radii in a table. The radius is changed to the next table setting after each LINAC pulse (6.67 Hz) and the table pattern repeats.



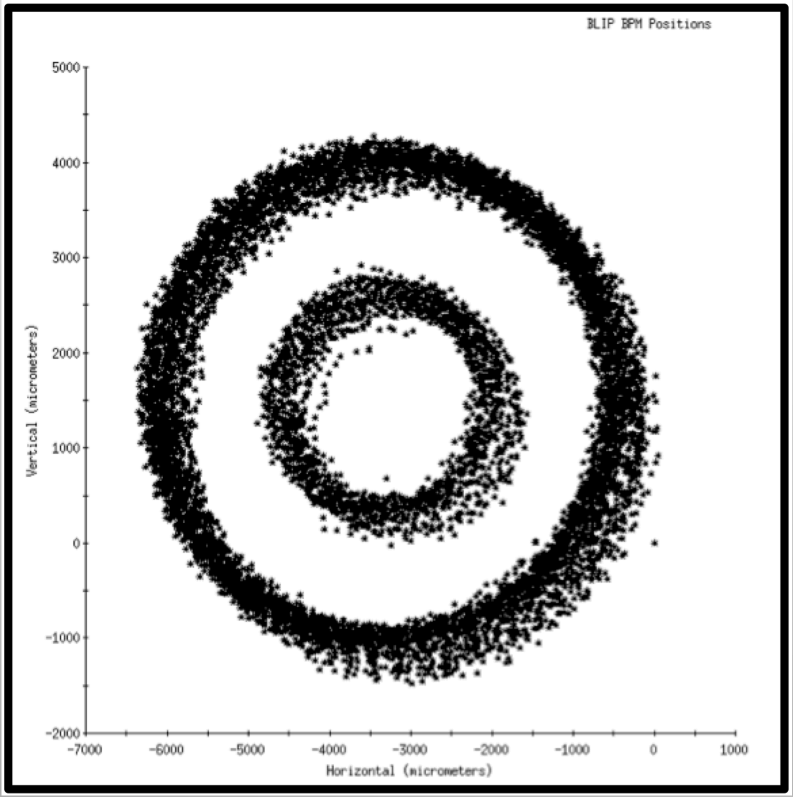
BLIP Raster System
Beam-line layout, photos, images, data
Beam position X vs. Y
Beam position vs. time
plunging multi-wire
raster magnet
vertical steering magnet
plunging multi-wire
laser profile monitor (LPM)
beam current transformers (2 places)
viewport and electron suppressor
concrete wall
6.5" collimator (internal)
beam position monitor (BPM)
aluminum bellows (existing)
alum. bellows
aluminum bellows
vacuum pump (existing)
4.5" collimator (internal)
LPM magnet
alum. bellows
beryllium window (existing)
location of targets
141.18" (358.60 cm)
existing to remain
BLIP beam current
milliAmps
Time (microseconds)
Beam current
X vs. Y
X and Y vs. time
Horizontal Laser Position (mm)
Vertical Laser Position (mm)
Horizontal Position (mm)
Vertical Position (mm)
magnetic field pickup coil data (5 kHz)
Beam profiles (LPM)
Beam profiles (multiwire)

Beam Current Measurements

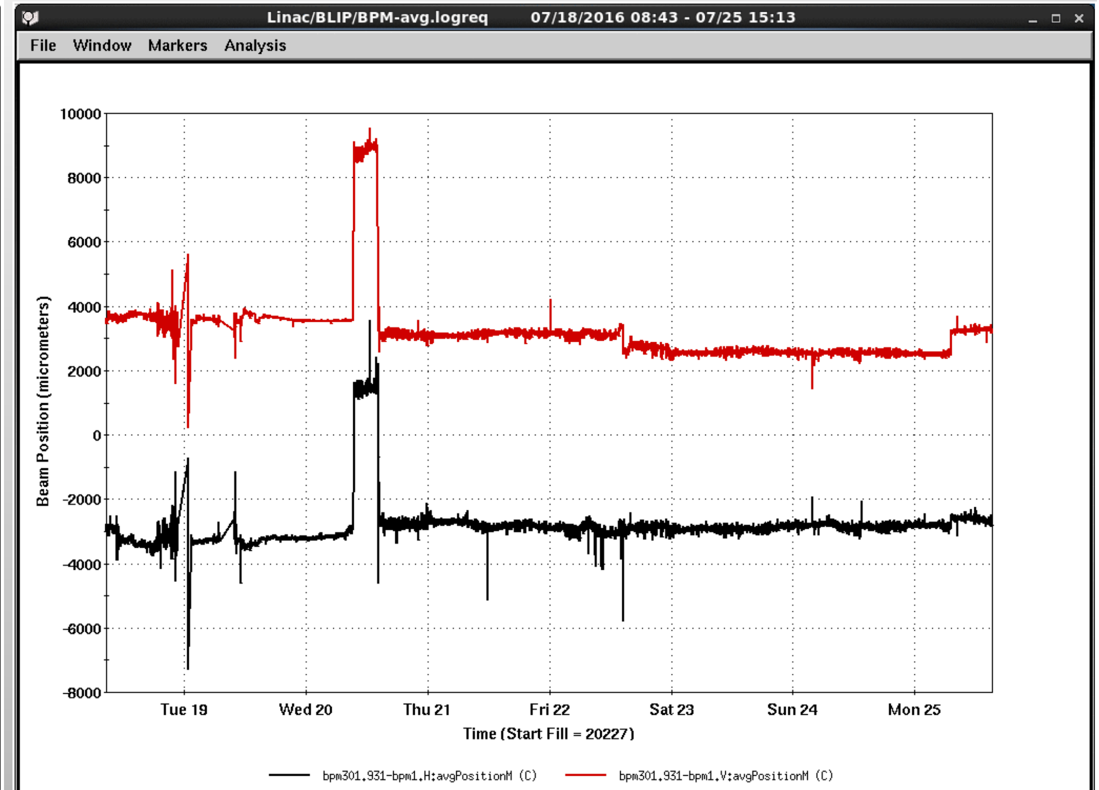


A 48-hour period (April 9-10, 2016) of the average beam current (black), and the running average (red) for 117 MeV Sr-82 production with the raster system on. Note that the average beam current is nearly steady at 160 μA for the entire period.

Beam Position Monitor Data



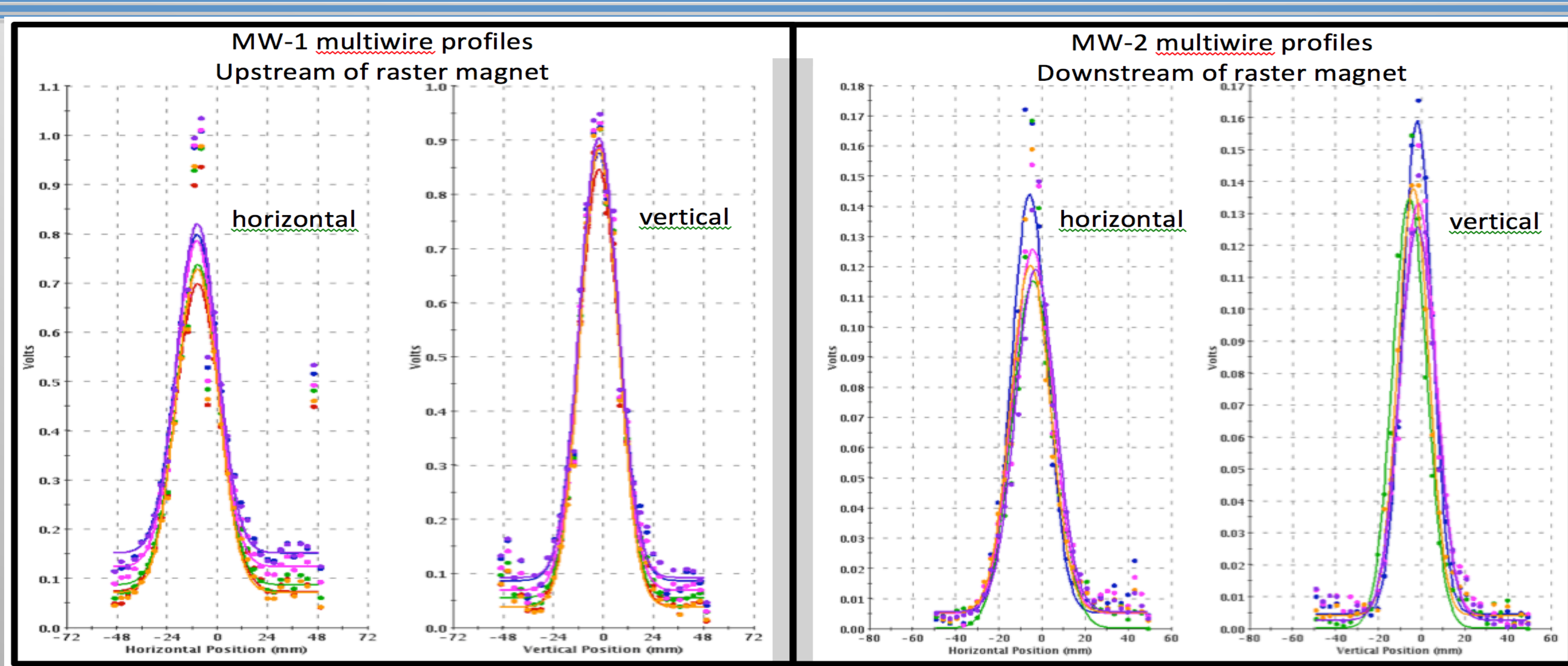
Beam position X vs. Y



Horizontal and vertical beam position vs. time for a period of about 1 week.

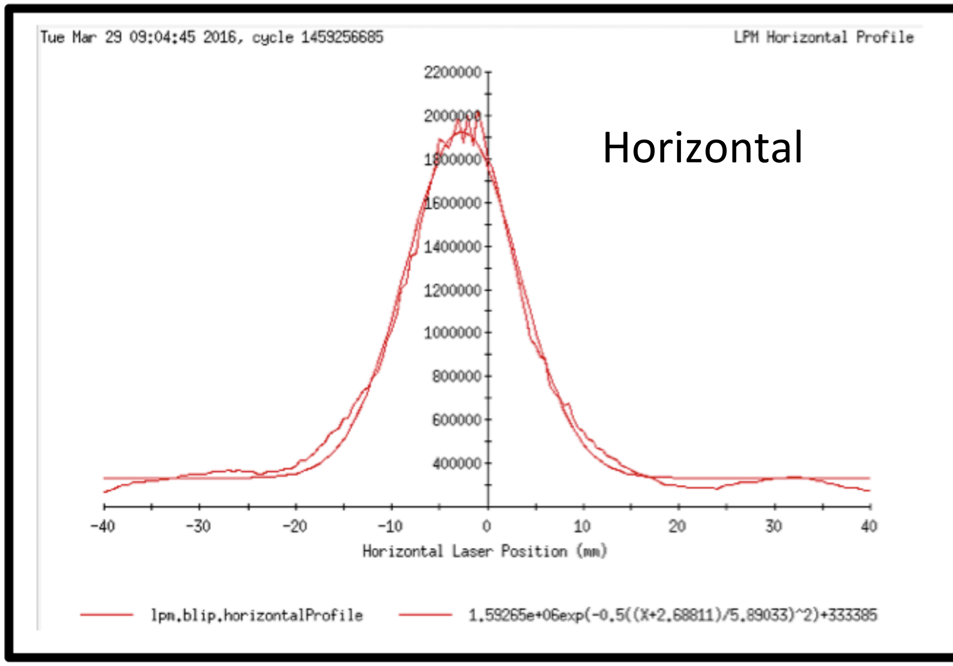
- Plot from March 30, 2016 with 117 MeV beam and raster pattern radii of 12.5 mm and 5.5 mm at the target.
- Actual position at BPM location is about 1.8 times the position shown in this plot

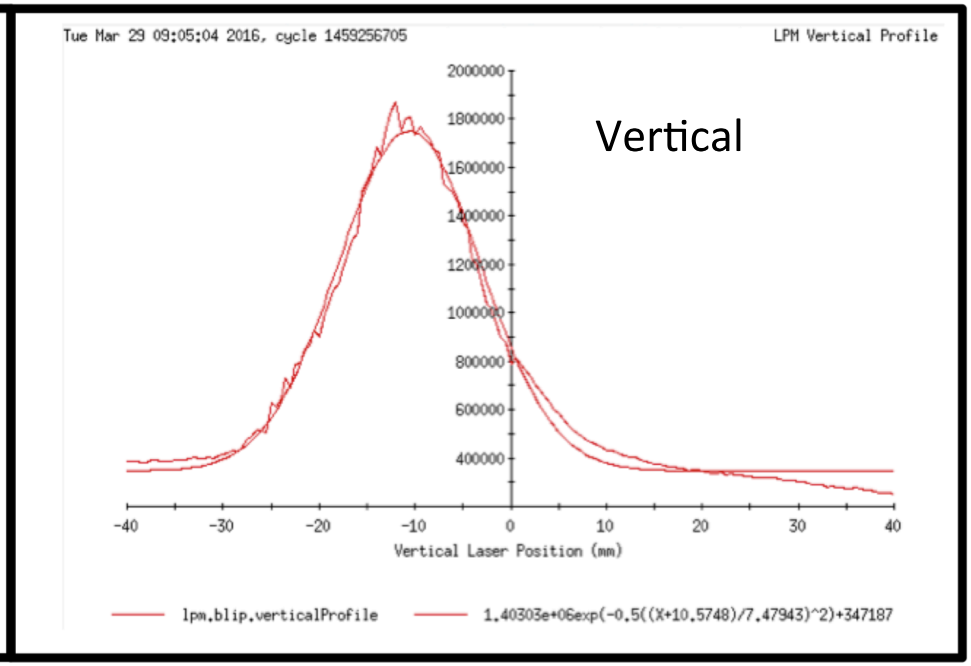
Multi-wire Profiles



- Profiles for six beam pulses are overlaid in each plot.
- y-scale is the integrated signal strength for each wire.
- Wire spacing is 3.175 mm and each plane has 32 wires.
- Profiles acquired with 117 MeV and with the raster on.
- Note that all overlaid profiles for MW-1 (upstream of raster magnet) are well aligned, while the overlaid profiles for MW-2 (downstream of raster magnet) are shifted with respect to each other. This is the expected beam raster behavior.

Laser Profile Monitor Scans

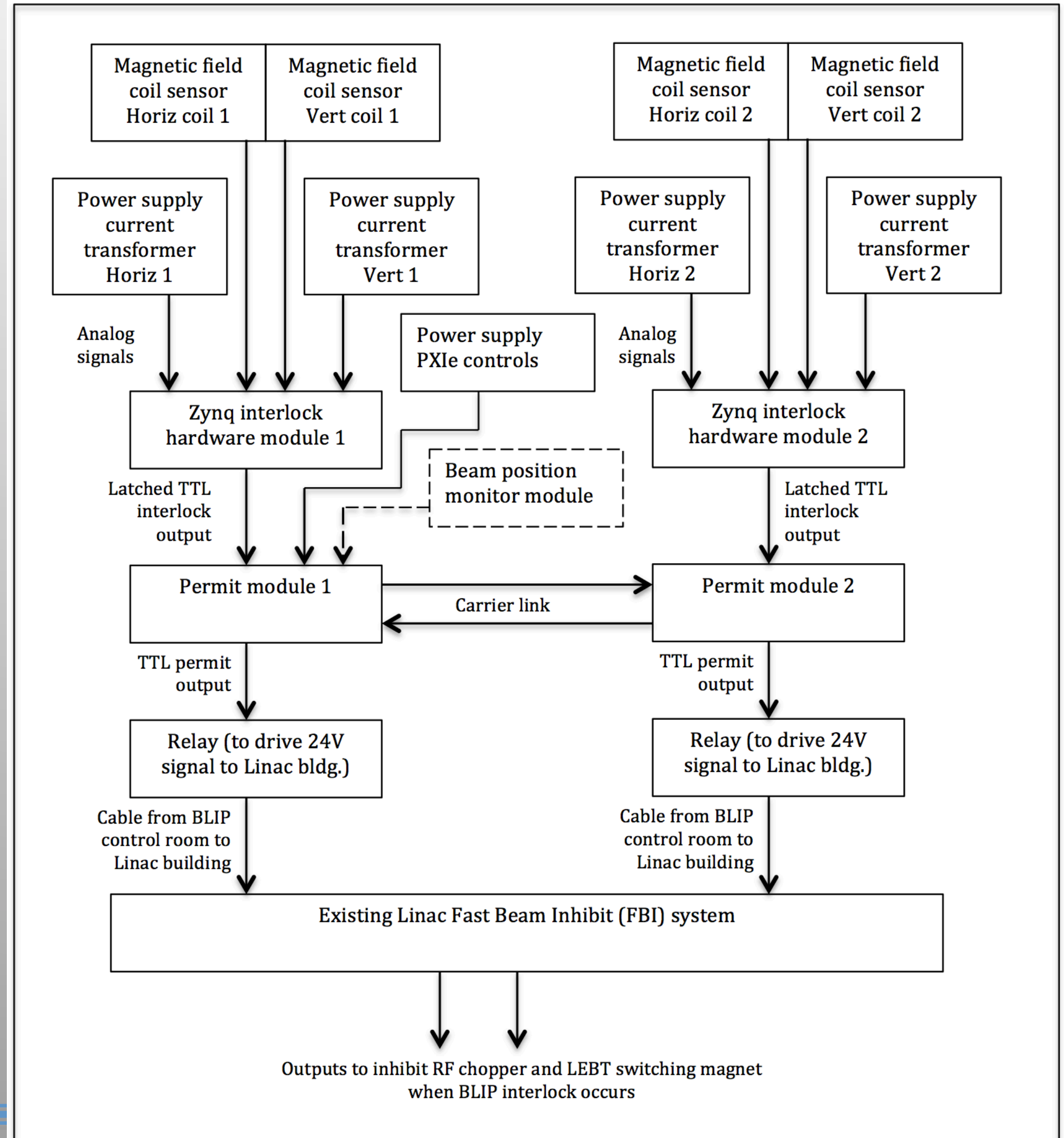




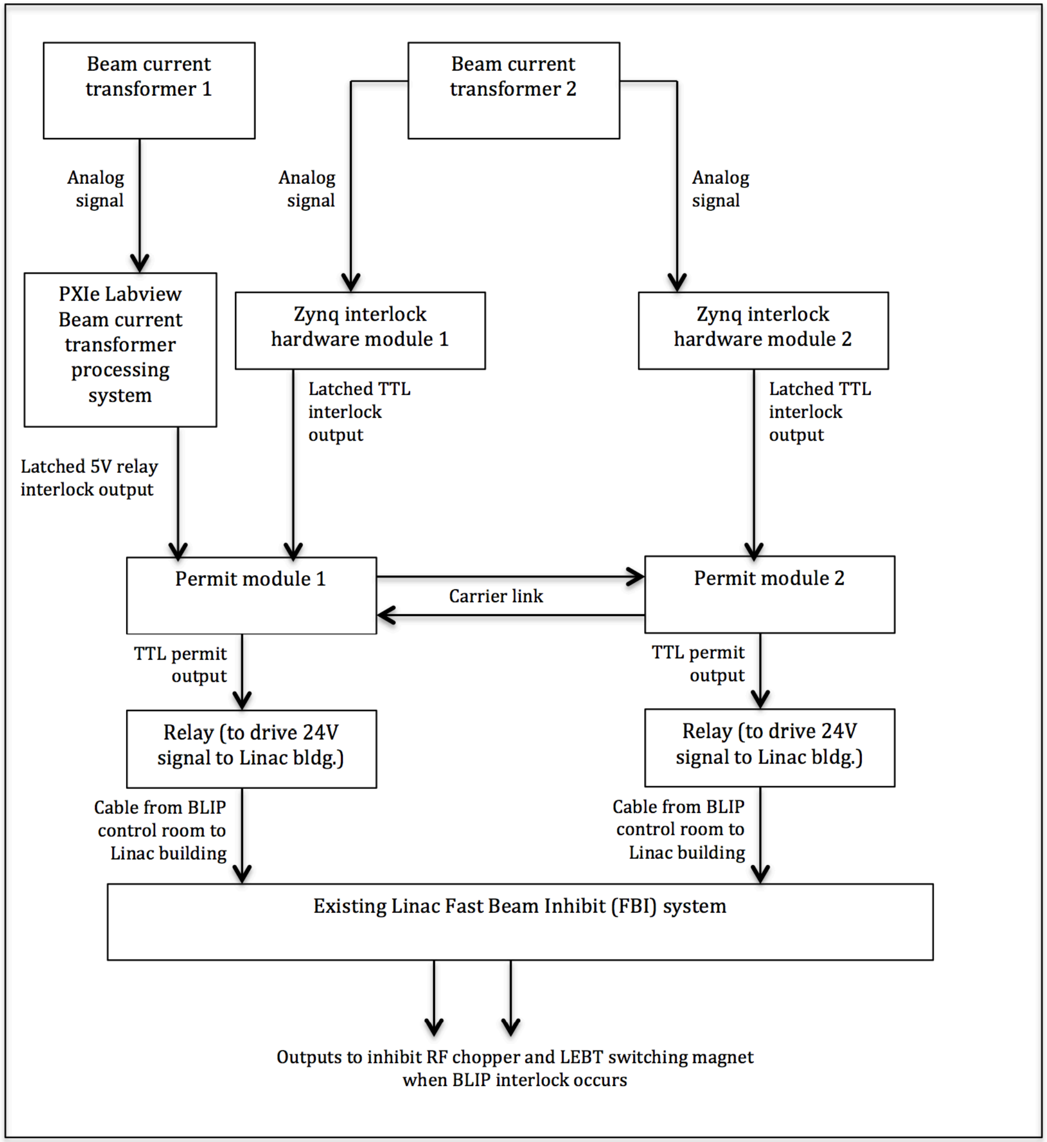
- Laser profile monitor data with curve fits, with raster on.
- y-scale is arbitrary units but is proportional to the number of electrons collected at each laser position.
- In these scans, the distance between each data point is 0.5 mm.
- A total number of 161 laser positions are provided.
- Each position value is the average of 24 points, where each point is a narrow slice of one beam pulse.

Interlock System (Raster not operating as expected)

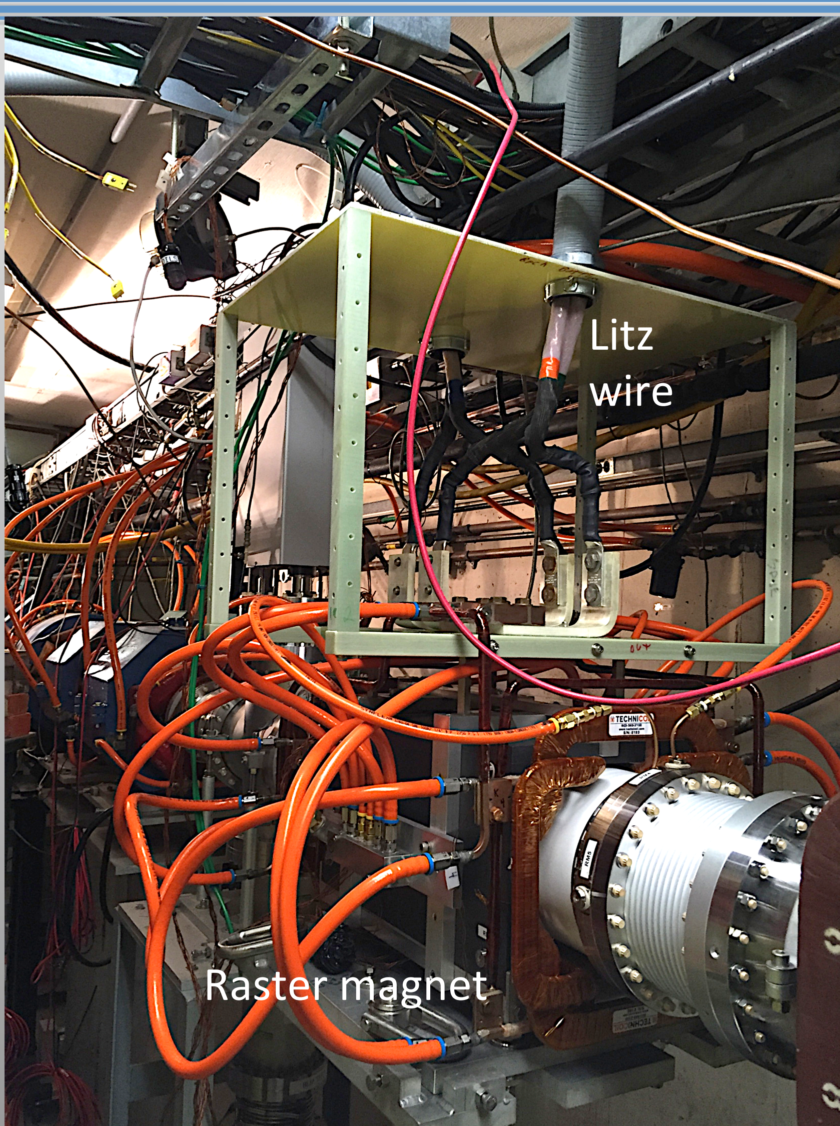
- Redundant signal paths are provided from the magnetic field coils and power supply current transformers to the Zynq interlock modules to the permit modules and to the relays and cables to the existing Linac Fast Beam Inhibit (FBI) system
- Fail-safe design
- Complete list of all conditions that can cause an interlock are defined in OPM 19-04-40-a.
- Test procedure for testing all interlock conditions is defined in OPM 19-04-40-b.



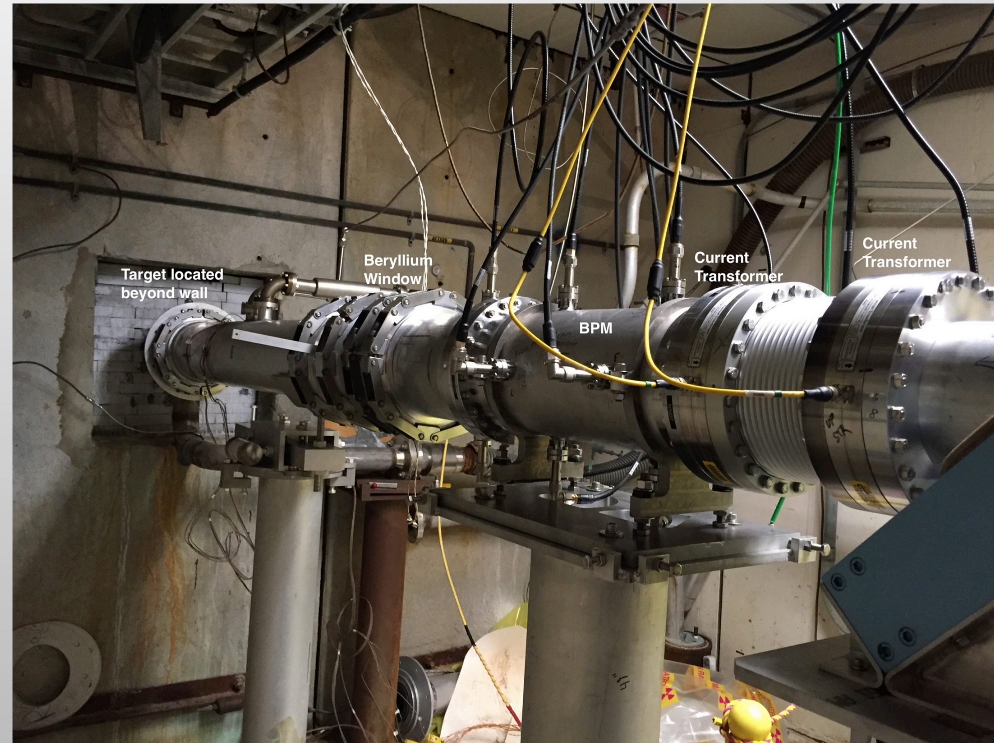
Interlock System (High Beam Current)



Tunnel Installation Photos

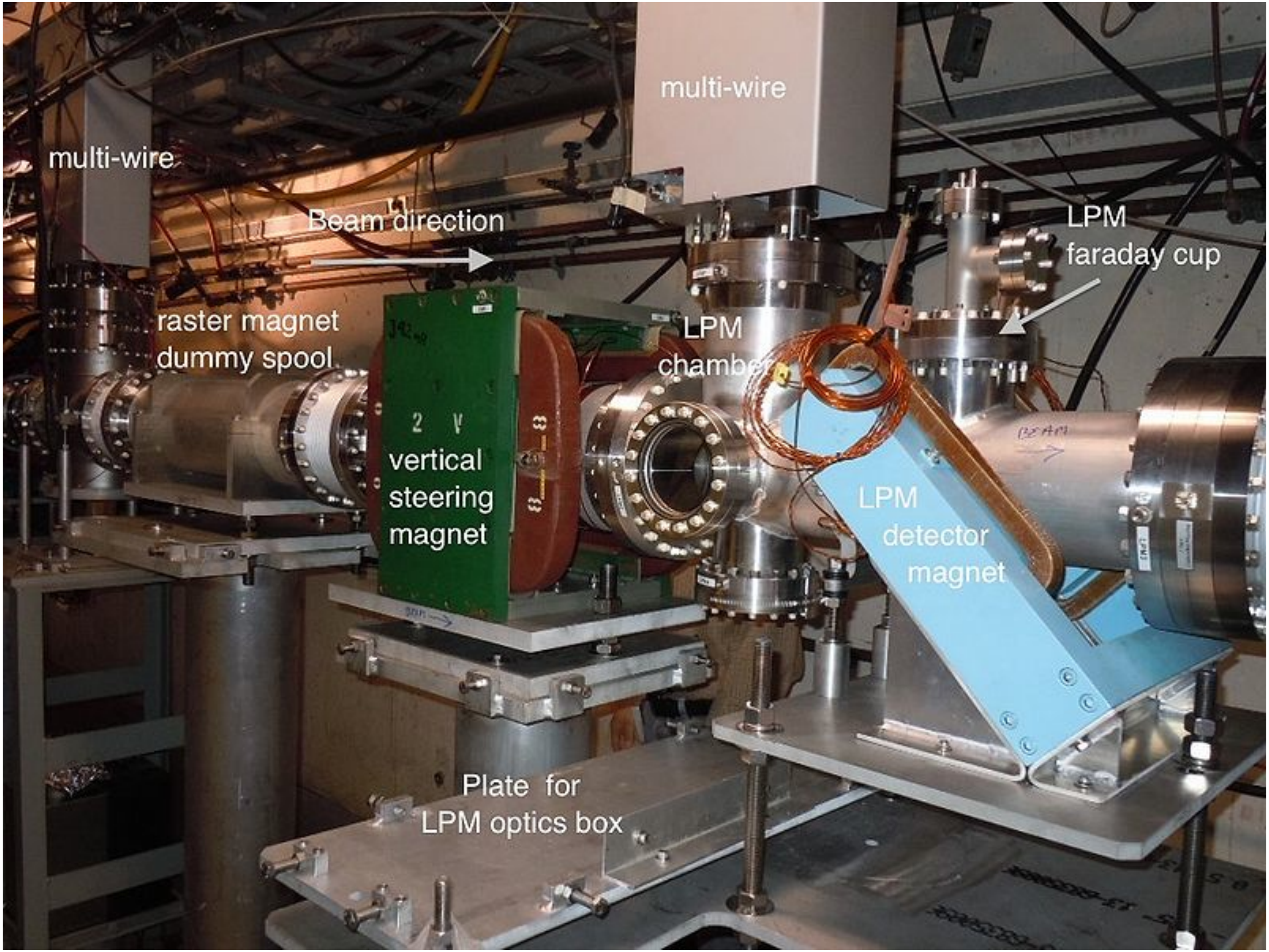


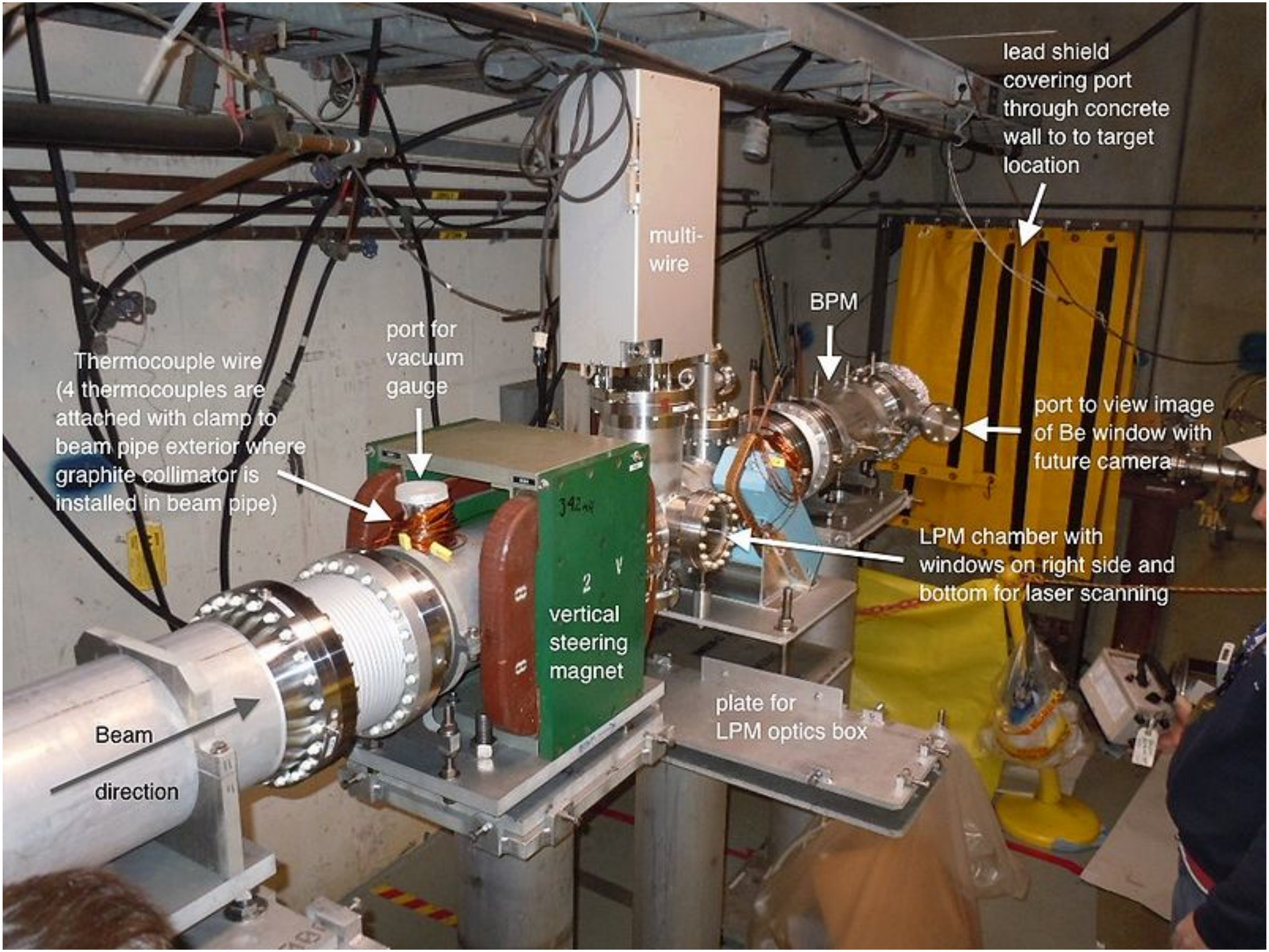
Upstream section of new beam-line
(beam direction is to the right)



Downstream section of beam-line
(beam direction is to the left)

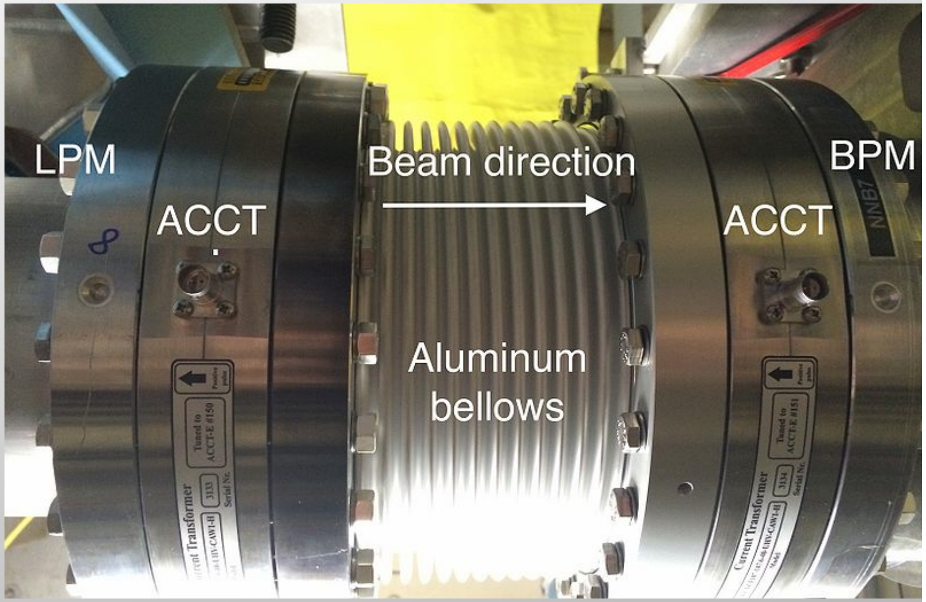
BLIP Control Room Equipment Racks

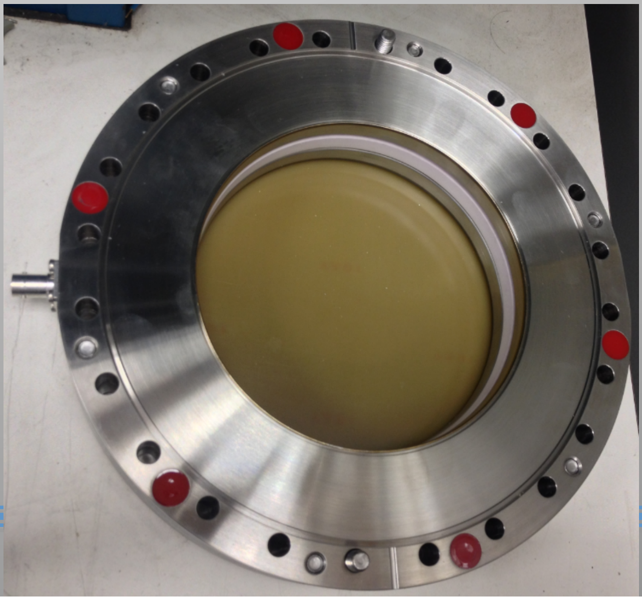

multi-wire
multi-wire
Beam direction
LPM
faraday cup
raster magnet
dummy spool
LPM
chamber
vertical
steering
magnet
LPM
detector
magnet
Plate for
LPM optics box


lead shield
covering port
through concrete
wall to to target
location
multi-
wire
BPM
port for
vacuum
gauge
Thermocouple wire
(4 thermocouples are
attached with clamp to
beam pipe exterior where
graphite collimator is
installed in beam pipe)
port to view image
of Be window with
future camera
LPM chamber with
windows on right side and
bottom for laser scanning
vertical
steering
magnet
plate for
LPM optics box
Beam
direction

Issues that arose

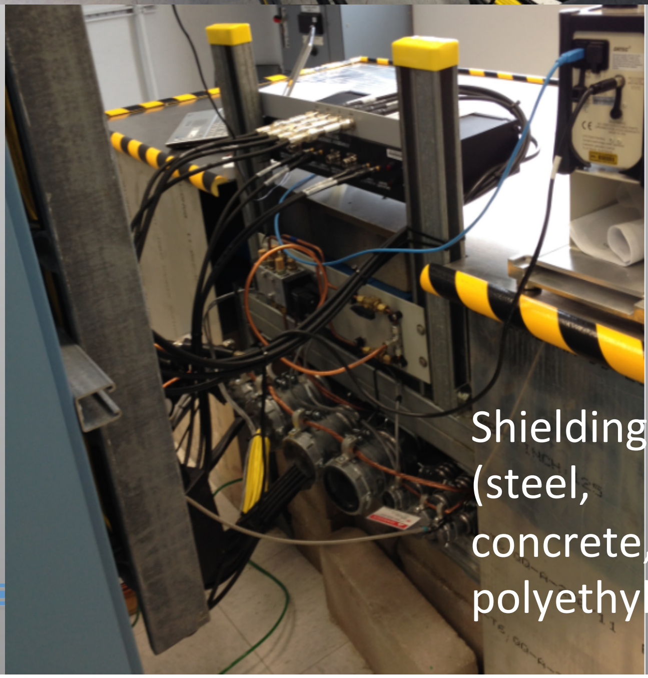
- A vacuum leak was found in one of the two Bergoz beam current transformers after installation in the beam tunnel.
  - Unfortunately, this device was not leak-checked upon delivery so we could not conclusively determine if the problem existed when the device was received.
  - The manufacturer concluded that the ceramic break was cracked.
  - The manufacturer is supplying a replacement unit at a substantial 30% discount in an effort to share the cost.
  - Lesson Learned: leak check every device at every stage of assembly.





Issues that arose

- Elevated levels of Oxygen-15 were detected in the BLIP control room soon after beam operations began. Although these levels were only 1% of the allowable limit, this was about 4x levels of previous years.
  - Cause was found to be air leaks from the beam tunnel through the cable penetration. This penetrations was sealed for many years until being open for installation of raster system cabling.
  - Air gaps in penetration were sealed with spray foam insulation and conduits were sealed with duct sealer.
  - Oxygen-15 levels are now similar to past years

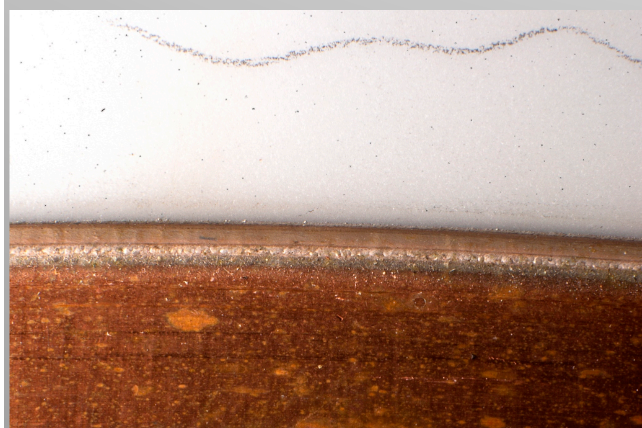


Issues that arose
Power supplies could not operate at full magnet design current

- After early testing of power supply and magnet system, learned that the magnet could not be operated at the full design current. The power supply current at 5kHz was limited to about 120 amps peak for continuous operation, significantly lower than the 318 amps design peak current.
  - The magnet losses were higher than anticipated, and thus caused limitations for the power amplifier output.
  - New matching transformers were purchased and installed to provide more optimal matching between the power amplifier output and the magnet resonant circuit. This ultimately allowed the system to be operated at the full 318 amp peak design current.
  - A magnet loss calculation error was found that fully explains the issue. Losses in the magnet coils were actually about 2x the originally calculated value.

Issues that arose
Magnet ceramic beam tube vacuum leak

- A vacuum leak was detected in the raster magnet ceramic beam tube transition section when final leak check was performed just prior to installation.
  - This required a total rebuild of the magnet using one of the spare ceramic beam tubes.
  - Exact cause is unconfirmed but is expected to be a defect in the transition brazing.
  - Other possible causes are vibration or heat.



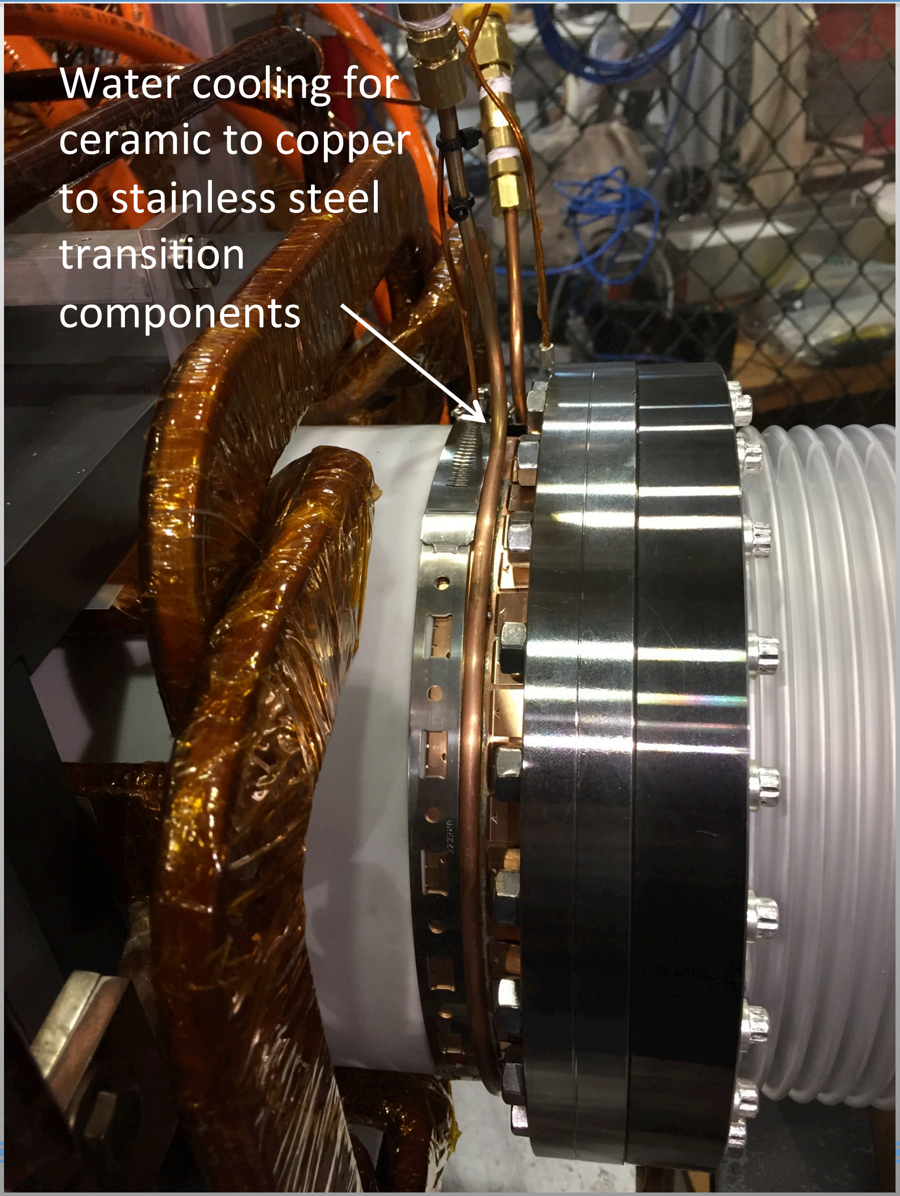
Zoom-in of normal section.

Zoom-in of failed section. Note cracks in brazing.

Failed ceramic beam tube. Leak detected at transition from ceramic to copper to stainless steel flange.

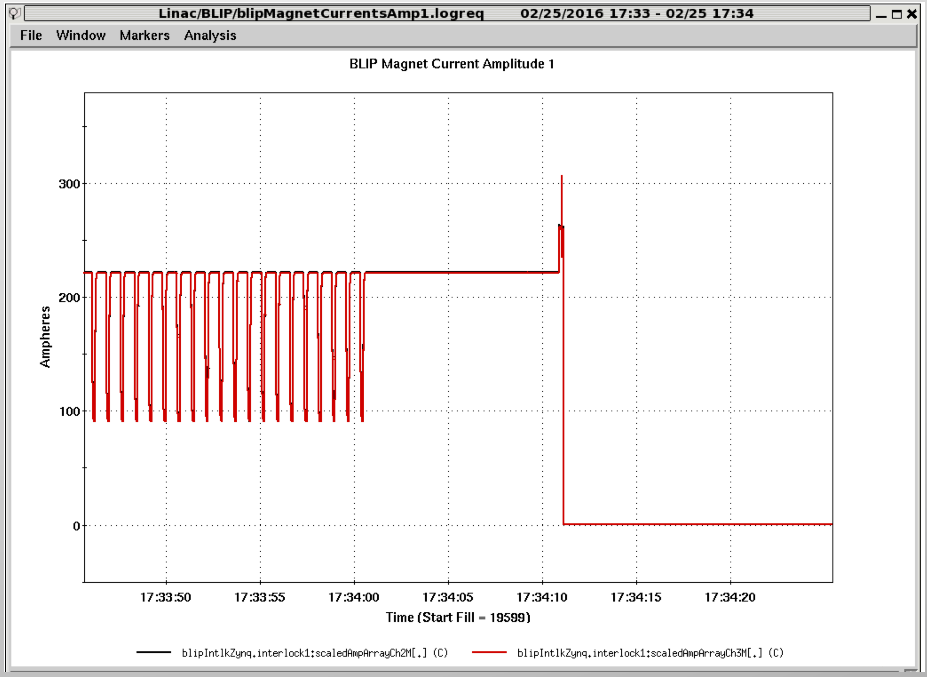
Issues that arose
Magnet ceramic beam tube vacuum leak

- To be conservative:
  - Maximum operational peak current will be limited to 260 Amps instead of the 318 Amp design current.
  - Water cooling was added to transition section.
  - Magnet current will be ramped up to heat components slowly and evenly.



Issues that arose
Raster Power Supply Trips

- The raster power supplies would periodically stop rastering as expected and output would drop to 0 Amps.
  - After difficult diagnosis, discovered that the National Instruments PXIe Labview code that delivers data via Ethernet occasionally holds off the control loop code execution, and thus causes the output to trip off.
  - The problem appears to be an issue in low level National Instruments code.
  - Presently operating with the Ethernet data delivery turned off. This has eliminated the issue.
  - Data delivery from the PXIe power supply controller is not essential since the power supply data are logged via the independent Zynq Interlock hardware system.



Recommended Use of Remaining Funding

Description	Estimated total cost (burdened)
Highest priority spares	$295,200
BM1 bending magnet power supply replacement	$249,000
Analysis of Gallium target failures	$100,000
Reserve	$5,500
TOTAL:	$649,700

Highest Priority Recommended Spares

Description	Qty	Probability of failure (low/medium/high)	Consequence of failure	Lead time	Estimated total cost (burdened)
1. Raster power supply spares					
1.1 Power amplifier	1	Medium	No rastering	12 weeks	$39,000
1.2 Matching transformers	2	Medium	No rastering	12 weeks	$9,600
1.3 Resonating capacitors	12	Medium	No rastering	16 weeks	$7,900
1.4 Voltage sensing xformers	4	Medium	No rastering	8 weeks	$3,200
1.5 PXIe controls	1set	Medium	No rastering	6 weeks	$43,500
2. Raster magnet		Medium	No rastering	24 weeks	
2.1 Ferrites	4			8 weeks	$24,800
2.2 Machined parts	1set			8 weeks	$26,400
2.3 Labor (eng, design, assy)				8 weeks	$118,300
3. Instrumentation					
3.1 ACCT PXIe controls	1set	Medium	Loss of beam current measurement, totals and interlock	6 weeks	$16,000
3.2 LPM laser fiber optic cable	1	High	Loss of LPM beam profile measurements	6 weeks	$6,500
				TOTAL:	$295,200

Other Recommended Spares

Description	Qty	Probability of failure (low/medium/high)	Consequence of failure	Lead time	Estimated total cost (burdened)
2. Raster magnet					
2.4 Beam tubes	2	Medium		8 months	$43,600
2.5 Beam tube coating	2			3 months	$23,400
3. Instrumentation					
3.3 Multiwire units	2	Medium (high after 5 years of operation)	No beam trajectory angle and position	7 months	$97,000
3.4 Beam current transformer	1	Low (high after 10 years of operation)	No beam current measurement	6 months	$42,000
3.4 LPM laser	1	medium	Loss of LPM beam profile measurements	12 weeks	$37,000
3.5 LPM current preamplifier	1	medium	Loss of LPM measurements	6 weeks	$3,500
3.6 Beam Position Monitor vacuum chamber	1	low	Loss of position measurements	20 weeks	$48,000
				TOTAL:	$294,500

Lessons Learned

- Extensive installation planning pays off. Taking the time to assemble the beam-line components in the lab prior to installation in the tunnel was time consuming, but very worthwhile. As a result, the installation time in the tunnel was significantly decreased, thus limiting worker exposure.
- Internal design reviews were very helpful in early identification of potential problems, thus helping provide early resolution.
- Risk analysis was very beneficial
  - For example, considering effects of radiation on equipment in the tunnel, led to careful analysis and development of a plan to use a combination of rad-hard equipment where feasible and the understanding that some equipment (e.g. cables) would be periodically replaced.

Lessons Learned

- Having a committed, focused team is essential to success.
  - Many personnel contribute, but a small nearly full-time core group makes all the difference
- With competing priorities, getting the right resources at the right time is often difficult, and work often takes longer than anticipated, but it does get done and it gets done well. Good planning is vital.
- Vacuum leak-check every component at each stage of fabrication.

Lessons Learned

- Tracking labor costs is difficult.
  - Reports are available on monthly basis only. This makes timely tracking of time spent on specific tasks very difficult.
- Competing priorities can inhibit ability to efficiently complete tasks.
- Inefficiencies exist.
  - Imprecise information can lead to assumptions
  - Redos can be expensive
    - Having well defined drawings or specifications can help prevent redos
    - Ensuring that the most up-to-date drawings are used can help prevent redos
    - This is R&D, so sometimes redos are beneficial. For example, after an assembly is completed, a better approach may be realized.
  - Multiple drawings sometimes have similar information. One group or individual prefers drawings in one format while others prefer different formats.

Lessons Learned

- Communication is hard.
- Everyone works differently.
- Need to provide a balance between well defined methods and procedures, and creating an environment that fosters creativity and allows some flexibility in the way work is performed.

BLIP Raster Project Team

- Leonard Mausner – Radioisotope Research Head
- Rob Michnoff – Project Manager
- Kerry Mirabella, Bob VanWormer, Khianne Williams – Project Controls
- Ed Lessard, Asher Etkin – Safety and QA
- Deepak Raparia – Accelerator Physicist; LINAC
- Chris Cullen – Mechanical Engineer; everything mechanical
- Bob Lambiase – Electrical Engineer; Raster power supply
- Roger Connolly – Instrumentation Physicist; LPM and more
- Peter Thieberger – Instrumentation Physicist; BPM simulations & modeling
- Rob Hulsart – Digital Engineer; BPM and more
- Steve Pontieri – Facilities Engineering
- Zeynep Altinbas – Power Supply Controls
- Chung Ho – Electrical Engineer; BLIP PLC
- Craig Dawson – Electrical Engineer; ACCT divider/driver circuit
- Winston Pekrul – Digital Engineer; beam interlock
- Phil Cerniglia, Tony Curcio, Dan Lehn – Technical coordination
- Chris Degen, LPM, Current Transformers
- Lenny DeSanto – LPM engineering consulting
- Many others – BLIP personnel, controls engineers, radiological control division personnel, mechanical technicians, electronic technicians, vacuum technicians, electricians, surveyors, cable pullers, riggers, central shops personnel, outside vendors

Summary

- Project is complete.
  - KPPs have been achieved
  - UPPs have been achieved with 1 exception
- Cost to complete the project was 86% of total original baseline budget (including contingency).
  - Only 14% of contingency funding was used.
- The system was available for operations 4 months earlier than planned.
  - System commissioning with beam began Dec. 16, 2015.
  - Isotope production with rastering began January 4, 2016.
- Significant performance improvements have been realized with the new raster system.
  - Total integrated current increased 48% from 2015 to 2016
  - Increase in yield (mCi/µAh) due to rastered beam has been calculated to be 9%
  - New instrumentation is directly attributable to improved beam stability